Age, growth and reproduction of the endangered jewelfish *Hemichromis bimaculatus* (Cichlidae) in the valley of Oued Righ (South-eastern Algeria)

by

Rabie GUEZI & M. Hichem KARA* (1)

Abstract. – Age, growth and reproduction of 493 jewelfish *Hemichromis bimaculatus* Gill, 1862 in the valley of Oued Righ (Algeria) were studied from December 2010 to December 2011. The total length and weight of the individuals ranged from 21 to 107 mm and 0.20 to 14.9 g, respectively. Monthly follow-up of the scale marginal growth allowed identifying only one growth stop annulus per year, occurring in April. Back-calculations of total length-at-age permitted to determine that the population was composed of three age classes in both sexes. The adjustment to von Bertalanffy growth model was satisfactory with $L_\infty = 11.6$ cm, K = 0.2, to = -0.5. The fitted total length-total weight relationship was $W = 0.026\ L^{2.803}$. Macroscopic examination of gonads and monthly follow-up of gonadosomatic index indicated that spawning occurred once a year between March and June with a peak activity in April-May. The GSI reached a maximum of 1.12% in males and 7.52% in females. The length at first maturity was 4.5 cm for males and 5.7 cm for females.

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Résumé. – Âge, croissance et reproduction de l'acara rouge *Hemichromis bimaculatus* dans la vallée de l'oued Righ (Algérie).

L'âge, la croissance et la reproduction de 493 Acaras rouges *Hemichromis bimaculatus* Gill, 1862 de la vallée de l'oued Righ (Algérie) ont été étudiés entre décembre 2010 et décembre 2011. La longueur totale et le poids total varient entre 21 et 107 mm et entre 0,20 et 14,9 g, respectivement. Le suivi mensuel de l'allongement marginal des écailles montre qu'il ne se forme qu'un seul anneau d'arrêt de croissance par an, en avril. Par rétro-calcul des tailles aux différents âges, trois cohortes ont été identifiées chez les deux sexes. L'ajustement du modèle de Von Bertalanffy aux données âge-longueur est satisfaisant avec $L_\infty = 11{,}6$ cm, K = 0,2, to = -0,5. La relation taille-poids est décrite par l'équation $Pt = 0{,}026\ Lt^{2{,}803}$. L'examen macroscopique des gonades et le suivi des variations mensuelles du rapport gonadosomatique indiquent que la reproduction a lieu une fois par an, entre mars et juin, avec un pic en avril-mai. Le RGS atteint un maximum de 1,12% chez les mâles et de 7,52% chez les femelles. La longueur des poissons à la première maturité sexuelle est de 4,5 cm pour les mâles et de 5,7 cm pour les femelles.

Key words
Cichlidae
Hemichromis bimaculatus
Algeria
Oued Righ
Growth
Reproduction

Genus *Hemichromis* lives only in Africa where it is represented by 11 species (Froese and Pauly, 2014), of which only three are described in North Africa: *Hemichromis fasciatus* Peters, 1857, *Hemichromis letourneuxi* Sauvage, 1880, and *Hemichromis bimaculatus* Gill, 1862 (García *et al.*, 2010). Only the last one is found in Algeria where it is autochtonous (Kara, 2012).

Hemichromis bimaculatus is widely distributed in West Africa, where it is known from most hydrographic basins (Teugels and Van Den Audenaerde, 2003), associated with forested biotopes. It is also reported from coastal basins of Cameroon, Democratic Republic of the Congo (Teugels, 1992) and northern regions (Algeria, Tunisia and Nile basin) (Kraiem, 1983; Le Berre, 1989; Kara, 2012), but not in Morocco (Azeroual *et al.*, 2000). According to the IUCN Red List of freshwater fish in Northern Africa, this species is critically endangered (García *et al.*, 2010).

Hemichromis bimaculatus is a benthopelagic fish that frequents fresh and brackish waters. It lives in zones with sandy bottoms or muds (Page and Burr, 1991), where it looks for prey (relatively great crustaceans, insects and other fishes) (Blay, 1985). The reproductive behaviour of this species contains fixed patterns, which are often organized in territorial, nest building, courtship and parental phases (Hildegard, 1985).

In North Africa, as in the entire African continent, biological information about *H. bimaculatus* is limited. In Nigeria, Hyslop (1987) studied some aspects of the biology of this fish in the Kandole Shela, and Ayoade and Ikulala (2007) in the Eleiyele Lake. In contrast, breeding behaviour of the species has attracted more attention (Figler *et al.*, 1975; Hildegard, 1984, 1985; David, 2007; Indira *et al.*, 2013), as well as its scale histology (Sire, 1981, 1982, 1989; Sire and Meunier, 1981; Sire and Géraudie, 1983, 1984). In Algeria, despite the recent updating attempts of freshwater fish species inventory (Bacha and Amara, 2007; Kara, 2012), efforts are still needed in some geographical areas. Moreover, the ecology and the biology of these species are generally

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(1) Marine Bioresources Laboratory, Annaba University Badji-Mokhtar, Annaba, Algeria. [rguezi@yahoo.fr]
* Corresponding author [kara_hichem@yahoo.com]

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unknown. This paper aims to determine the characteristics of the age, growth and reproduction of *Hemichromis bimaculatus* in the valley of Oued Righ in south-eastern Algeria.

MATERIALS AND METHODS

Study area and sampling

The valley of Oued Righ is located in the northeastern Sahara desert of Algeria (Low Sahara basin), which occupies an area of about 600,000 km^2. It extends about 160 km from “El Goug” in the South to “ Oum El Thiour” in the North, with an average width ranging between 30 and 40 km in a south-north direction (Fig. 1). More exactly, the study area lies between 32°53’5”-34°10’0”N and 5°47’50”-6°10’00”E. The climate along this area is arid to hyperarid, characterized by low rainfall and high rates of evapotranspiration. Daily mean temperatures vary between 10°C in the winter to 32°C in the summer, with August being the hottest month. Rainfall is generally low and tends to fall between November and March. The average annual rainfall is approximately 58 mm (Halis *et al.*, 2012).

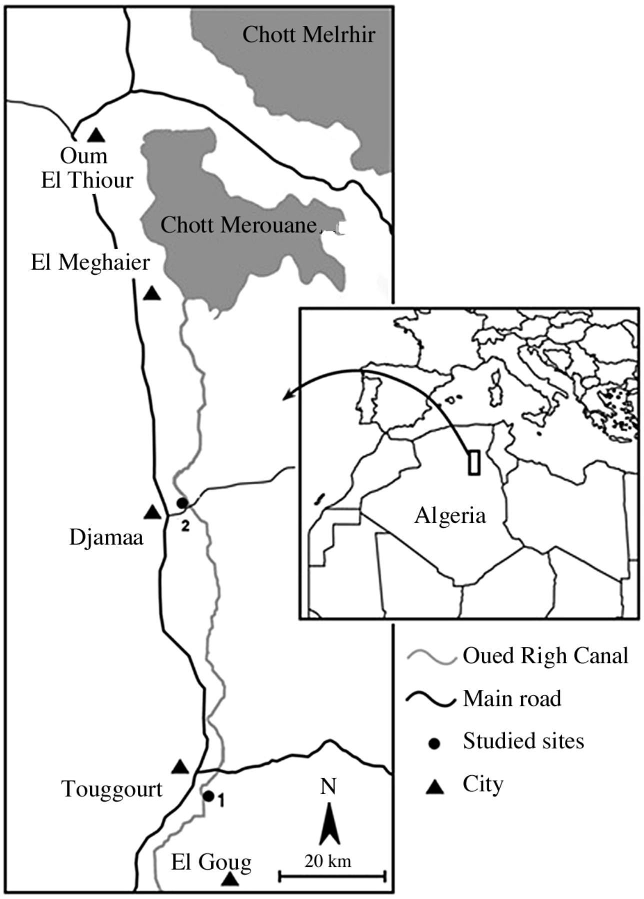

Figure 1. - Map of the Valley of Oued Righ with the location of the sampling localities. 1: Temacine Lake, 2: Oued Righ Channel.

H. bimaculatus samples were obtained monthly from December 2010 to December 2011 in two communicating sampling localities (Temacine Lake and Oued Righ Channel) (Fig. 1).

Age and growth

Scales of *Hemichromis bimaculatus* were placed between two glass slides and were photographed with a digital camera coupled with a binocular microscope. The photographs were digitally processed and used for calibration, measurements and quantification of growth increments of calcified structures. The digital processing was made using the TNPC software v. 5. (Fablet and Ogor, 2005). This software measured the distance between the focus and the different annuli and the marginal increment. Annuli are translucent zones under transmitted light (Panfili *et al.*, 2002). Five to seven scales were removed from under the left pectoral fin. The total scale radius (R) and the radii of the different growth rings (R1, R2,… Rn) were measured along a median vertical line (Fig. 2).

In order to determine when these rings formed, we analyzed monthly variations of the relative marginal scale increment (MI), with $MI = R - Rn / Rn - Rn^{-1}$, where Rn and Rn^{-1} are the radius of the last and the next-to-last growth rings, respectively (Panfili *et al.*, 2002). Individual age was determined taking into account the date of capture, the mean birth date (June) and time of annulus formation (May) according to Panfili *et al.* (2002). In this case, every growth ring corresponds to one year age.

The age-length relationship was back-calculated according to the Lee method (1920). The theoretical size of fishes when the first scales formed was obtained by a regression TL = f (R) based on 402 data ($21.9 \leq TL \leq 101$ mm, $6.6 \leq R \leq 27.3$ mm). Observed lengths were compared with the results of the back-calculation. The von Bertalanffy (1938) growth function was fitted to the length and age data and is expressed as: $TL = L\infty\ [1 - e^{-K\ (t - t_0)}]$, where TL is the length at age t, K is a constant determining the rate of change in the length increment and t_0 is the age of the fish at zero length. The regression equation for the length-weight relationship was estimated by the least squares method with log transformed data by the equation: $W = aL^b$, where W is the total body weight (g) and L is the total length (mm). All these parameters were determined using Fishparm software (Saila *et al.,* 1988).

Reproduction and sex maturity

We calculated the sex ratio (SR) according to season and by function of length. SR values were calculated as follows: SR = number of males / number of females. To quantify the changes in gonad weight during the annual sexual cycle and to determine the spawning season, we calculated the gonadosomatic index (GSI) for 426 mature specimens

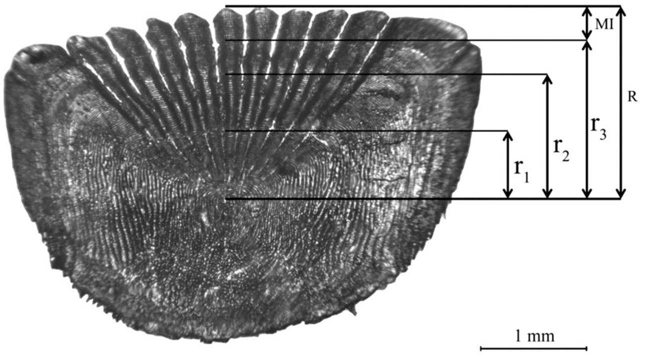

Figure 2. - Scale of *Hemichromis bimaculatus* (3 years old, TL = 9.30 cm), caught in Oued Righ valley (r_1 = first annulus, r_2 = second annulus, r_3 = third annulus; MI = marginal increment; R = total radius)

Table I. - Distribution of individual total lengths of *Hemichromis bimaculatus* males and females from the valley of Oued Righ, obtained from direct scale readings. sd = standard deviation

Length interval (cm)	Age (years)						Number of sampled fish	
	1		2		3			
	M	F	M	F	M	F	M	F
[3.6-3.9[	1	2					1	2
[3.9-4.2[	4	2					4	2
[4.2-4.5[	10						10	–
[4.5-4.8[	2		6	4			8	4
[4.8-5.1[			9	8			9	8
[5.1-5.4[			13	11			13	11
[5.4-5.7[			11	8			11	8
[5.7-6.0[			4	5			4	5
[6.0-6.3[			6	11			6	11
[6.3-6.6[			2	13			2	13
[6.6-6.9[			7	21		3	7	24
[6.9-7.2[			6	21	5	7	11	28
[7.2-7.5[			2	10	7	23	9	33
[7.5-7.8[					11	13	11	13
[7.8-8.1[					14	6	14	6
[8.1-8.4[					10	2	10	2
[8.4-8.7[					13	6	13	6
[8.7-9.0[					9	1	9	1
[9.0-9.3[					2		2	0
[9.3-9.6[					2	2	2	2
[9.6-9.9[					1		1	–
[9.9-10.2[					1		1	–
Total	17	4	66	112	75	63	158	179
%	10.75	2.23	41.77	62.56	47.46	35.19		
Mean length	4.26	4.28	5.73	6.28	8.17	7.64		
sd	0.24	0.15	0.78	0.79	0.63	0.57		
Mean weight	1.45	1.3	3.69	5.00	10.05	8.59		
sd	0.37	0.11	1.71	1.86	2.82	4.72		

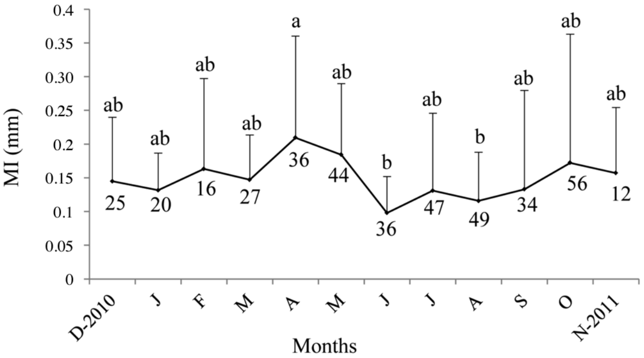

Figure 3. - Monthly variation of the marginal increment (MI) of scales of *Hemichromis bimaculatus* in the valley of Oued Righ. The different letters indicate significant differences between sampling points. Error bars correspond to standard deviations.

Table II. - Back-calculated total lengths (cm) at the appearance of each growth ring in the scales of *Hemichromis bimaculatus* females and males from the valley of Oued Righ, Algeria. Ages I to III represent the age obtained from direct scale readings. TL1 to TL3 are the back-calculated sizes-at-age. N: number, M: mean, Sd: standard deviation, TL: total length.

Age (years)		TL (cm)			Age (years)		TL (cm)		
Females		TL1	TL2	TL3	Males		TL1	TL2	TL3
1	N	4			1	N	17		
	M	5.00				M	4.97		
	Sd	0.42				Sd	0.58		
2	N	111	111		2	N	66	66	
	M	4.76	6.10			M	5.11	5.93	
	Sd	0.43	0.61			Sd	0.58	0.78	
3	N	63	63	63	3	N	75	75	75
	M	5.65	6.49	7.10		M	5.49	6.64	7.12
	Sd	0.45	0.47	0.39		Sd	0.64	0.85	0.91
Total	N	178	174	63	Total	N	158	141	75
	M	5.53	6.24	7.10		M	5.276	6.649	7.127
	Sd	0.45	0.60	0.39		Sd	0.669	0.892	0.915

(214 females and 212 males) by the following formula: GSI = GW.100 / EW, where GW: gonad weight (g) and EW: eviscerated weight (g). The hepatosomatic index was also calculated monthly: HSI = LW.100/EW, where LW: liver weight (g) and EW: eviscerated weight (g). The condition coefficient (K) values were calculated as follows: K = EW.100/TL^3, where EW: eviscerated weight (g) and TL: total length (cm). The size at first sexual maturity was determined by the evolution of the proportion of mature fish according to size class during the reproduction period. Length at first maturity was estimated as the length at which 50% of the fish had become mature (TL_{50}) (Rikhter and Efanov, 1976). Gonads were visually assessed for their stage

Table III. - Comparison of the observed lengths with back-calculated lengths at different ages for the *Hemichromis bimaculatus* in the valley of Oued Righ. M = males, F = females, *t*: *t-test*, *P* = significance level.

Age (years)	Sex	Observed length	Back-calculated length	*t*	*p*
1	M	4.26	5.27	1.02	0.96
	F	4.28	5.53	1.18	0.43
2	M	5.73	6.64	1.48	0.13
	F	6.28	6.24	0.43	0.07
3	M	8.17	7.12	0.57	0.06
	F	7.64	7.10	0.64	0.14

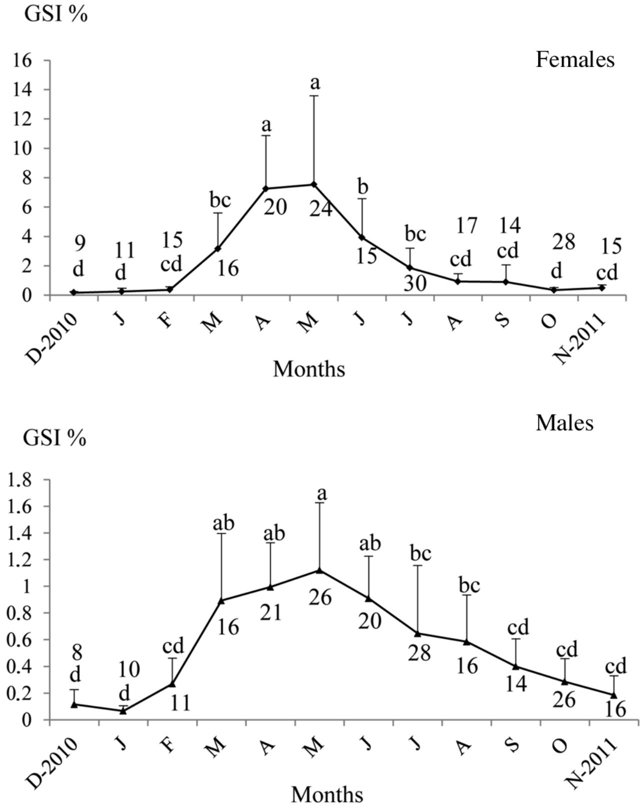

Figure 4. - Monthly variation of the gonadosomatic index (GSI) of *Hemichromis bimaculatus* females and males in the valley of Oued Righ. The different letters indicate significant differences between sampling points. Error bars correspond to standard deviations.

Table IV. - Seasonal variation of sex-ratio (SR) of *Hemichromis bimaculatus* in the valley of Oued Righ.

Month	Males	Females	SR	χ^2
Summer	50	54	0.92	0.15
Autumn	54	51	1.05	0.08
Winter	39	46	0.84	0.57
Spring	69	63	1.09	0.27
Annual	212	214	0.99	0.009

Table V. - Number of males and females and sex-ratio (SR) as a function of length in *Hemichromis bimaculatus* in the valley of Oued Righ.

Length (cm)	Males	Females	SR	χ^2
3.75	4	1	4	–
4.25	17	9	1.88	2.46
4.75	16	10	1.6	1.38
5.25	25	19	1.31	0.81
5.75	13	13	1	–
6.25	11	20	0.55	2.61
6.75	19	38	0.5	6.33
7.25	28	52	0.53	7.2
7.75	20	28	0.71	1.33
8.25	25	12	2.08	4.56
8.75	17	11	1.54	1.28
9.25	8	4	2	1.33
9.75	3	1	3	–
10.25	1	1	1	–

of maturation according to Babiker and Ibrahim (1979). We adopted this scale thanks to the similarities in the gonad appearance observed during the different periods of the sexual cycle. Stages of maturation were classified as follows: I, immature; II, maturing; III, mature IV, ripe; and V, spent. A female is considered mature when the ovaries are in stages II to V, and for males when testicles are in stages II to IV (Núñez and Duponchelle (2009)).

Statistical analysis

Comparison of MI, GSI, HSI and K values between months were carried out by analysis of variance (ANOVA) completed by Newman-Keuls. Observed lengths at different ages were compared with the back-calculation results obtained by Student t-test. The same test was used to compare male and female growth using back-calculated length at age values. The overall sex-ratio was tested monthly using chi-square test (Dagnélie, 1973). Statistical analyses were performed with Xlstat_Pro_7.5 software.

RESULTS

Age, growth and length-weight relationships

The linear regression of total length versus scale radius was TL = 2.54 R – 1.80 ($r = 0.76$ $p \leq 0.001$). The intercept of this equation (1.8 mm) corresponds to the theoretical size of fish at the time of formation of the first scales. Comparing successive monthly mean scales marginal increment values (Fig. 3) using mean comparison tests, showed a significant difference ($p \leq 0.001$) between April and June. The value of the marginal increment is at its minimum (0.09 mm) when the ring is forming during June.

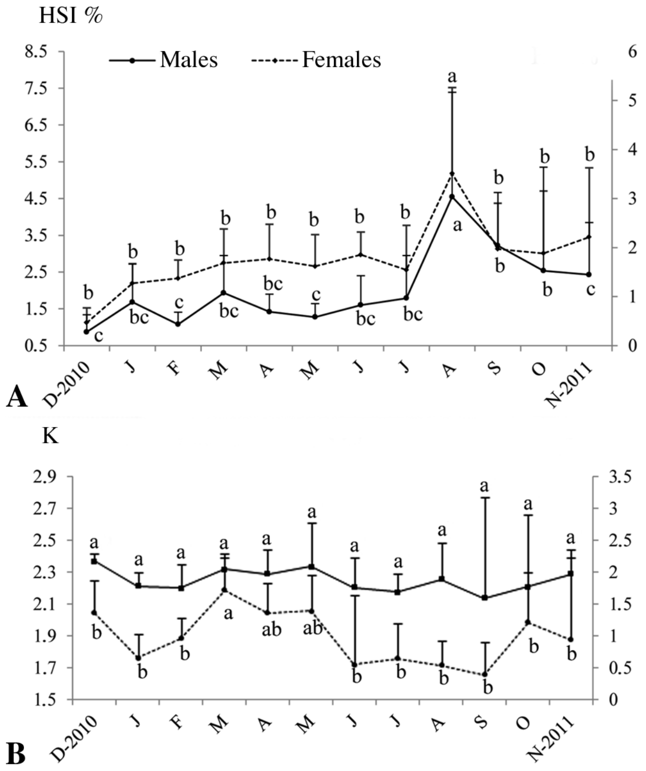

Figure 5. - Monthly variation of the hepatosomatic index (**A**), HSI and the condition factor (**B**), K of *Hemichromis bimaculatus* in the valley of Oued Righ. The different letters indicate significant differences between sampling points. Error bars correspond to standard deviations.

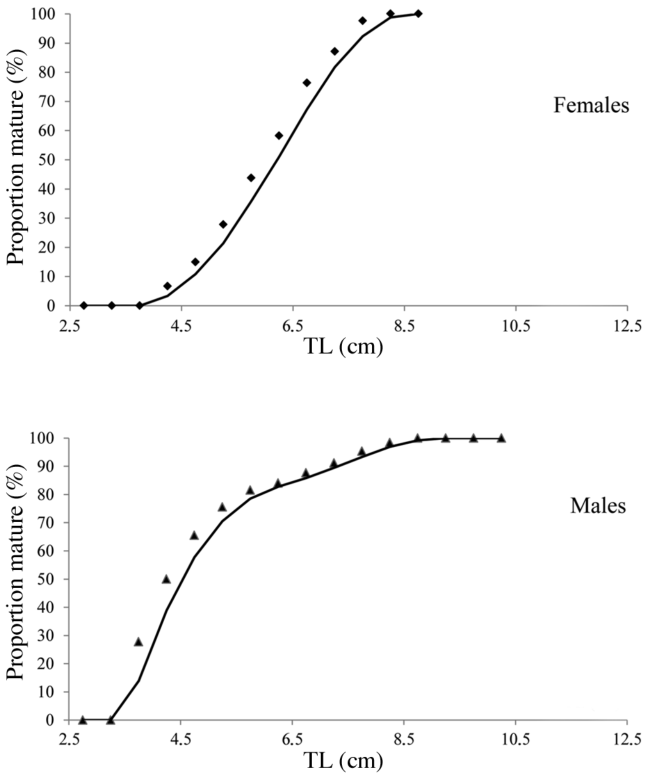

Figure 6. - Proportion of mature individuals (%) by total length for females and males of *Hemichromis bimaculatus* in the valley of Oued Righ.

Three age classes, from 1 to 3 years old, were found for males and females. About 6.23% of *H. bimaculatus* belonged to the age group 1 year old, 52.82% to age group 2 years old and 40.94% to 3 years old (Tab. I). Back-calculated age-length pairs for females and males are given in table. II. Observed lengths at different ages did not vary significantly with the back-calculation (Tab. III). The estimated parameters of Von Bertalanffy's model are: $L\infty = 11.6$ cm, $K = 0.5$ year^{-1}, $t_0 = -0.2$. The weight-length relationship is $W = 0.026\ L^{2,803}$ ($r = 0.93$).

Reproduction

Global sex-ratio for 214 females and 212 males is 1:0.99 ($\chi^2 = 0.009$, $p > 0.05$). This value is constant throughout year and season (Tab. IV). In females, monthly evolution of GSI indicated a breeding season occurring between March and June, with a peak in April-May. The evolution of the GSI in males was almost similar to that observed in females (Fig. 4). The maturation phase of gametes was between February and March. The maximum value of the GSI was observed in May; afterwards the values of the GSI began to decrease. The hepatosomatic index (HSI) for both sexes gradually increased from December to August. The HSI reached its maximum in August with 3.50% and 4.54% for females and males, respectively, and attained its minimum in December for females (0.46%) and for males (0.87%) (Fig. 5A). Monthly variations in the condition coefficient (K) were not perceptible in males (around 1.87) (Fig. 5B). In females, a significant increase occurs between February (1.88) and March (2.18). The size at which 50% of the population reaches maturity is 4.5 cm for males and 5.7 cm for females (Fig. 6).

DISCUSSION

Annuli formation on the scales of *H. bimaculatus* off Oued Righ Valley occur during May-June. This period of slower growth may result from the intense gametogenetic activity between February and May. Man and Hodgkiss (1977) found that annuli formation is induced by low growth due to a low feeding intensity, but also by periods of low water temperature, which are observed in our studied area during February (15.4° C) and March (18.9° C) (Gouasmia, pers. comm.).

H. bimaculatus is a short living species in Oued Righ Valley. Its size ranged from 3.6 to 10.2 cm and its age is between 1 and 3 years for males and females. As reported by Indira *et al*. (2013), the longevity can attain 5 years. The growth of this species is correctly described by the Von Bertalanffy model. Unfortunately, data on *Hemichromis* genus growth do not exist as far as we know, and comparisons are not possible. The length-weight relationships in this species indicated close to negative allometric growth (b = 2.80). A similar result was recorded in Ivory Coast (b = 2.88) (Lévêque, 2006) and in Eleiyele Lake in Nigeria with a weak value in this case (b = 2.14) (Ayoade and Ikulala, 2007). Variations should be attributed to various factors, which can affect fish growth, and can include season, habitat, gonadal maturity, sex, stomach fullness, health and/or preservation techniques (Nikolsky, 1963; Tesch, 1968).

Analysis of the GSI suggests that the spawning period takes place in the spring season, from March to June, with a resting period during the rest of the year. The breeding season coincides with the hottest times of the year. A similar spawning period of *H. bimaculatus* is found in Ivory Coast (Albaret, 1982). According to Indira *et al*. (2013) in India, the species has a major spawning season coinciding with the northeast monsoon during October-November, having the spawning peak in mid-November and a minor spawning season synchronizing and responding to the south-west monsoon in April-June. In Kandole Shela (Northern Nigeria), spawning of *H. bimaculatus* occurs in May-June, which is before or coincident with the beginning of the wet season, probably to fit maximum number of broods into the period of food abundance (Hyslop, 1987).

Variations of HSI values indicate that *H. bimaculatus* saves lipid reserves in the liver just after the breeding season (August). A reversion of trophic activity following this period of eventual fast may explain this situation. Indeed, fishes, which decrease their food intake during gonadal maturation, use nutrients originating from endogenous reserves in muscle, adipose tissue and liver (Lal and Singh, 1987; Nassour and Léger, 1989; Martin *et al*., 1993).

The stability of K values (1.87 ± 0.40) in males during the year indicates that the populations keep the same condition during the different seasons. In females, the high values of K during breeding season (1.65 to 2.18) may be due to favourable trophic conditions that compensate for the energy expense of gamete production. In Kandole Shela (Northern Nigeria), these values range between 1.63 and 1.93 (Hyslop, 1987).

The length at first maturity of the jewelfish of Oued Righ valley is 4.5 cm for males and 5.7 cm for females. These values are different from those in India (51-55 mm (1st method) or 53 mm (2nd method) for females and 61-65 mm (1st method) or 65 mm (2nd method) for males (Indira *et al*., 2013) and in Ivory Coast (4.5 cm for females) (Albaret, 1982). These variations could be related to environmental factors (temperature, latitude of sampling areas). In a number of cichlid species, *Tilapia nilotica* (Babiker and Ibrahim, 1979), *Tilapia zilli* (Dadzie and Wangila, 1980), *Tilapia leucosticta* (Trewavas, 1933) and *Oreochromis macrochir* (Boulenger, 1912), males and females mature at different sizes. It is accepted that the optimum size for the first maturation depends upon many factors, including the relative allocation of food energy between somatic and gonad growth (Mazzoni and Caramaschi, 1995).

This paper provides the first data on the biology of *H. bimaculatus* in North Africa. Growth and reproduction were monitored during one year-cycle. Results are still to be debated with further incoming data on feeding habits, ecology and eventual population genetics studies, that may explain the patchy geographic repartition of such sensitive fish. Our study and the resulting guidelines for the management of the Jewelfish will enable the conservation of an endangered species known to be impacted by both environmental- and human-induced factors.

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REFERENCES

ALBARET J.J., 1982. - Reproduction et fécondité des poissons d’eau douce de Côte d’Ivoire. *Rev. Hydrol. Trop*., 15: 347-371.

AYOADE A. & IKULALA A., 2007. - Length weight relationship, condition factor and stomach contents of *Hemichromis bimaculatus*, *Sarotherodon melanotheron* and *Chromidotilapia guentheri* (Perciformes: Cichlidae) in Eleiyele Lake, Southwestern Nigeria. *Rev. Biol. Trop*., 55: 969-977.

AZEROUAL A., CRIVELLI A.J., YAHYAOUI A. & DAKKI M., 2000. - L’ichtyofaune des eaux continentales du Maroc. *Cybium*, 24: 17-22.

BABIKER M. & IBRAHIM H., 1979. - Studies on the biology of reproduction in the Cichlid *Tilapia nilotica* (L.): gonadal maturation and fecundity. *J. Fish Biol*., 14: 437-448.

BACHA M. & AMARA R., 2007. - Les poissons des eaux continentales d’Algérie. Étude de l’ichtyofaune de la Soummam. *Cybium*, 31: 351-358.

BLAY J., Jr., 1985. - Observations on the balance in fish populations in a small reservoir in Ghana. *Fish. Res*., 3: 1-11.

DADZIE S. & WANGILA B., 1980. - Reproductive biology, length-weight relationship and relative condition of pond raised *Tilapia zilli* (Gervais). *J. Fish. Biol*., 17: 243-253.

DAGNÉLIE P., 1973. - Théorie et Méthodes statistiques : Application agronomiques, Vol. 1. La statistique descriptive et les fondements de l’inférence statistique. 2nd édit., 378 p. Gembloux: Presses agronomiques.

DAVID L.J.A., 2007. - Efecto del sexo del cíclido joya (*Hemichromis bimaculatus*) (Pisces: Cichlidae) ante los cambios de temperatura. *An. Univ. Etol*., 1: 53-57.

FABLET R. & OGOR A., 2005. - TNPC (digital processing of calcified structures): user manual. www.ifremer.fr/lasaa/tnpc.

FIGLER M.H., DYER R.S., STRECKFUS C.F. & NARDIN K.M., 1975. - The establishment of dominance relationships in the jewel fish, *Hemichromis bimaculatus*, as related to prior exposure to and configuration of visual cues. *Behav. Biol.*, 14(2): 241-245.

FROESE R. & PAULY D. (eds), 2014. - FishBase [Accessed Jul. 2014]. http://www.fishbase.org.

GARCÍA N., ABDUL MALAK D., KRAÏEM M., SAMRAOUI B., AZEROUAL A., CUTTELOD A., FISHAR M.R., YAHYAOUI A. & MELHAOUI M., 2010. - The status and distribution of freshwater fish. *In*: The Status and Distribution of Freshwater Biodiversity in Northern Africa (García N., Cuttelod A. & Abdul Malak D., eds), pp. 13-28. Gland, Switzerland, Cambridge, UK, & Malaga, Spain: IUCN. https://cmsdata.iucn.org/downloads/the_status_and_distribution_of_freshwater_biodiversity_in_northern_africa.pdf

HALIS Y., BENHADDYA M.L., BENSAHA H., MAYOUF R., LAHCINI A. & BELHAMRA M., 2012. - Diversity of halophyte desert vegetation of the different saline habitats in the valley of oued Righ, low Sahara basin, Algeria. *Res. J. Environ. Earth Sci.*, 4(3): 308-315.

HILDEGARD C., 1984. - Behavioral effects of TRH, 3-Me-His2-TRH and naloxone in *Hemichromis bimaculatus*. *Pharmacol. Biochem. Behav.*, 21: 727-732,

HILDEGARD C., 1985. - Effects of MET-ENK, Substance P and SRIF on the behavior of *Hemichromis bimaculatus*. *Peptides*, 6: 139-148.

HYSLOP E.J., 1987. - Aspects of the biology of *Hemichromis bimaculatus* from a small stream in Nigeria. *J. Fish Biol.*, 31: 745-751.

INDIRA R., ARACHI J.P. & VARADHARAJAN D., 2013. - Studies on the reproductive biology of red jewel cichlid *Hemichromis bimaculatus* (Gill, 1862). *Int. J. Environ. Biol.*, 3: 160-172.

KARA M.H., 2012. - Freshwater fish diversity in Algeria with emphasis on alien species. *Eur. J. Wildl. Res.*, 58: 243-253.

KRAIEM M., 1983. - Les poissons d'eau douce de Tunisie : inventaire commenté et répartition géographique. *Bull. Inst. Natl. Sci. Tech. Océanogr. Pêche Salammbô*, 10: 107-124.

LAL B. & SINGH T., 1987. - Changes in tissue lipid levels in the freshwater catfish *Clarias batrachus* associated with the reproductive cycle. *Fish. Physiol. Biochem.*, 3: 191-201.

LE BERRE M., 1989. - Faune du Sahara. 1. Poissons, amphibiens, reptiles. Séries "Terres africaines", 332 p. Paris: Éditions Lechevalier & R. Chabaud.

LEE R.M., 1920. - A review of the methods of age and growth determination in fishes by means of scale. *Fish. Invest.*, 2(4): 1-32.

LÉVÊQUE C., 2006. - Croissance et ontogénie. *In*: Les Poissons des Eaux continentales africaines: Diversité, Ecologie, Utilisation par l'Homme (Lévêque C. & Paugy D., eds), pp. 183-184. IRD Éditions.

MAN H.S. & HODGKISS I.J., 1977. - Studies on the ichthyofauna in Plover Cove Reservoir, Hong Kong: Feeding and Food relations. *J. Fish Biol.*, 11(1): 1-13.

MARSHALL B., 1979. - Observations on the breeding biology of *Sarotherodon macrochir* (Boulenger) in Lake Mcllwaine, Rhodesia. *J. Fish Biol.*, 14: 419-424.

MARTIN N.B., HOULIHAN D.F., TALBOT C. & PALMER R.M., 1993. - Protein metabolism during sexual maturation in female Atlantic salmon (*Salmo salar*). *Fish. Physiol. Biochem.*, 12: 131-141.

MAZZONI R. & CARAMASCHI E., 1995. - Size structure, sex ratio and onset of sexual maturity of two species of *Hypostomus*. *J. Fish Biol.*, 47: 841-849.

NASSOUR I. & LÉGER C.L., 1989. - Deposition and mobilisation of body fat during sexual maturation in female trout (*Salmo gairdneri* Richardson). *Aquat. Living Resour.*, 2: 153-159.

NIKOLSKY G.V., 1963. - The Ecology of Fishes (Translated by L. Birkett). 352 p. London: Academic Press.

NÚÑEZ J. & DUPONCHELLE F., 2009. - Towards a universal scale to assess sexual maturation and related life history traits in oviparous teleost fishes. *Fish. Physiol. Biochem.*, 35: 167-180.

PAGE L.M. & BURR B.M., 1991. - A Field Guide to Freshwater Fishes: North America North of Mexico. 432 p. Boston: Houghton Mifflin.

PANFILI J., DE PONTUAL H., TROADEC H. & WRIGHT P.J., 2002. - Manual of Fish Sclerochronology. 464 p. Brest, France: Ifremer-IRD coedition.

RIKHTER V.A. & EFANOV V.N., 1976. - On one of the approaches to estimation of natural mortality of fish populations. International Commission for the Northwest Atlantic Fisheries Research Document, 76: 8-12.

SAILA S.B., RECKSIEK C.W. & PRAGER M.H., 1988. - Basic Fishery Science Programs: a Compendium of Microcomputer Programs and Manual of Operation (Developments in Aquaculture and Fisheries Science). 236 p. Elsevier Science.

SIRE J.Y., 1981. - La scalation : apparition et mise en place des écailles chez *Hemichromis bimaculatus* (Gill, 1862) (Téléostéens, Perciformes, Cichlidés). *Cybium*, 5: 51-66.

SIRE J.Y., 1982. - Regeneration of scales in a Cichlid, *Hemichromis bimaculatus* (Teleostei, Perciformes). 1. Morphogenesis, structure and mineralization. *Ann. Sci. Nat. Zool. Biol. Anim.*, 4: 153-169.

SIRE J.Y., 1989. - The same cell lineage is involved in scale formation and regeneration in the teleost fish (*Hemichromis bimaculatus*). *Tissue Cell*, 21: 447-462.

SIRE J.Y. & GÉRAUDIE J., 1983. - Fine structure of the developing scale in the Cichlid *Hemichromis bimaculatus* (Pisces, Teleostei, Perciformes). *Acta Zool.*, 64: 1-8.

SIRE J.Y. & GÉRAUDIE J., 1984. - Fine structure of regenerating scales and their associated cells in the Cichlid *Hemichromis bimaculatus* (Gill). *Cell Tissue Res.*, 237: 537-547.

SIRE J.Y. & MEUNIER F., 1981. - Structure et minéralisation de l'écaille d'*Hemichromis bimaculatus* (Téléostéen, Perciforme, Cichlidé). *Arch. Zool. Exp. Gen.*, 122: 133-150.

TESCH F.W., 1968. - Age and growth. *In*: Methods for Assessment of Fishes Production in Freshwater (Ricer W.E., ed.), pp. 93-123. IBP Handbook, Blackwell Science Pub, 3.

TEUGELS G.G., 1992. - Clariidae. *In*: Faune des Poissons d'Eaux douces et saumâtres de l'Afrique de l'Ouest, Tome 2 (Levêque C., Paugy D. & Teugels G.G., eds), pp. 468-495. Collection Faune tropicale XXVIII. Paris & Tervuren: ORSTOM & MRAC.

TEUGELS G.G. & VAN DEN AUDENAERDE D.F.T., 2003. - Cichlidae. *In*: Faune des Poissons d'Eaux douces et saumâtres de l'Afrique de l'Ouest, Vol. 2 (Paugy D., Lévêque C. & Teugels G.G., eds), pp. 520-600. Collection Faune et Flore tropicales. Paris & Tervuren: IRD, MNHN, MRAC.

VON BERTALANFFY L., 1938. - A quantitative theory of organic growth. *Hum. Biol.*, 10: 181-213.